Chapter 1

Characterizing Medical Wastes and Applying a Comprehensive Management Strategy

The Medical Waste Tracking Act (MWTA) of 1988 represents an attempt by Congress to address the problems of beach washups and illegal disposal of medical wastes.[1] A more comprehensive approach to medical waste management, one consistent with the broader waste management strategy evolving nationally, could be formally established if the issue of medical wastes remains part of the current RCRA reauthorization effort. Medical wastes need to be put into a broader frame of reference along with other wastes (e.g., municipal and industrial hazardous and nonhazardous wastes) if we are to establish appropriate levels of protection for humans and the environment. The relative risks posed by all these types of wastes must be considered when determining appropriate management methods for them.

This chapter consists of a brief discussion of the context within which the current Federal approach to waste management for other hazardous and nonhazardous wastes evolved and consideration of the implications of a broader, more comprehensive waste management strategy for medical waste. Appendix A to this report provides a short review of MWTA, the first major Federal effort to address medical wastes.

MEDICAL WASTE IN A COMPREHENSIVE WASTE MANAGEMENT STRATEGY

The Resource Conservation and Recovery Act (RCRA),[2] passed by Congress in 1976, is the major Federal statute addressing management of the Nation's wastes—hazardous, municipal, industrial, and other types of solid waste, including medical waste.[3] EPA has authority under RCRA to regulate the handling, storage, treatment, transportation, and disposal of all of these wastes. Before passage of MWTA, EPA's activity regarding medical waste issues was mostly limited to distribution of its guidance document for the management of infectious wastes. Other medical wastes were considered to be like any other solid waste and subject to relevant RCRA Subtitle D regulations (114).

OTA finds four key challenges which need to be resolved for medical waste management:

1. better defining/identifying infectious and other medical wastes, to facilitate more consistent and adequate handling and treatment of wastes;
2. better addressing the diversity of generators (e.g., home health care, small doctors' offices, clinics, etc.) to minimize contradictory requirements and inequities they pose;
3. improving the segregation of wastes for their proper treatment; and
4. identifying appropriate treatment alternatives.

The very nature of these issues indicates that a comprehensive, flexible, yet cost-conscious approach is needed for medical waste management. These challenges can be met by a broader approach to medical waste management that emphasizes waste prevention efforts and management of different portions of the medical waste stream based on their physical, chemical, and biological (i.e., infectious) properties. Such a comprehensive approach to waste management is beginning to be applied to hazardous waste and more recently to municipal solid waste (MSW).

[1]Congress also amended the Marine Protection, Research, and Sanctuaries Act (also known as the Ocean Dumping Act) in 1988 to increase the penalties for illegal disposal of medical wastes by public vessels (33 U.S.C. 1401 et seq.). See app. A and (115) for discussion of MWTA.

[2]Public Law 94-580 (1976); 42 U.S.C. 6901 et seq. The Solid Waste Disposal Act of 1965 (Public Law 89-272; as amended by the Resource Recovery Act of 1970, Public Law 91-512) was the law by which Congress first established a Federal role in solid waste management. The most recent major revision of RCRA was by the Hazardous and Solid Waste Amendments of 1984 (Public Law 98-616), which did not address medical waste issues in any detail. RCRA is currently in the process of further revision and reauthorization.

[3]OTA (115) recently completed its assessment of municipal solid waste, of which the 1988 background paper on medical wastes was a part. Currently, OTA is completing a background paper on industrial solid (Subtitle D, RCRA) waste issues (expected to be released in early 1991). Hazardous waste issues have been addressed by several OTA reports (e.g., 112, 113).

It should be noted that the following discussion is based in part on ref. 137.

Photo credit: L. Swanson

Beach washups containing medical debris, such as syringes, helped prompt passage of the MWTA. Subsequent studies indicate the sources of most washups to be related more directly to sewage treatment systems operation than illicit waste management practices.

There is some consensus that at least portions of the medical waste stream can be treated like other MSW. Indeed, in practice this appears to occur. The California Air Resources Board reports, as noted above, that typically 40 percent or more of the waste burned by medical waste incinerators in their State is waste, comparable to MSW in nature (106, 108, 29).[4] Available evidence also seems to indicate that most medical waste poses no more public health or environmental hazard when properly handled than does MSW (109, 56, 107, 139). Yet, when medical waste is incinerated (or treated by some other means) its emissions may be hazardous if not properly controlled (as is the case with any other waste). Thus, basic policy determinations regarding management approaches, and weighing risks and costs, etc., are common to any waste problem.

It is instructive to consider the current trends in hazardous waste and MSW treatment in which there is a movement away from treatment methods that manage indiscriminately *mixed* wastes and toward source separation programs that encourage management based on the properties of the materials in the wastes (e.g., recyclability, ability to destroy or neutralize, etc.). OTA's assessment of the MSW issue found that environmentally sound waste management requires focusing on how the Nation uses materials from manufacturing through subsequent distribution and disposal (116). On this basis, OTA concluded that,

> A clear national policy on MSW that addresses the use of materials is essential for providing a broader context in which specific MSW programs can be developed and implemented. Waste prevention and materials management should be the foundation of this policy.

The basic steps are: 1) characterizing the waste stream in light of categories used for different alternative treatment options; 2) segregating wastes at the point of origin to facilitate management based on their characteristics; and 3) examining the production of the waste, i.e., looking upstream to consider possible opportunities for waste reduction (in either volume or toxicity) that may include use of different products which are reusable or recyclable or contain less problematic substances for waste treatment.

For example, government agencies and/or the health-care industry could examine prospects for waste reduction in health-care settings (see ch. 2). Although the growth in the volume of medical wastes is not well documented, there is general acknowledgment that the use of disposables in health care has increased significantly in the last two decades. Clearly, in some cases the use of disposables is important for infection control. Yet, those uses driven primarily by economies may need to be reassessed (see ch. 2).

From a management perspective, the presumption held by some regulators and members of interest groups that incineration is the "preferred" treatment option for medical wastes warrants closer examination. Most of the recent regulatory activity for medical waste management at all levels of government tends to focus on incineration and does not usually include specific procedures for the regulatory approval of nonincineration alternatives.

For example, the "treat and destroy or track" requirement of MWTA does not include a process with specific criteria for how the standard can

[4]Based on this type of information, emission data from medical and MSW facilities can be compared, as long as the type and size of incinerator or other technology and the mix of wastes is taken into account (see ch. 5).

be met by various treatment alternatives, and does not specify how new non-incineration treatment alternatives can be introduced. A number of such alternatives (e.g., several types of disinfection units) are commercially viable and warrant consideration (see ch. 3).

Further, a number of unanswered questions remain regarding incineration, e.g., the nature of emissions and proper controls, the nature and adequate treatment of ash residues, and the cost compared with alternative management methods (see ch. 4). Information on operating parameters, risks, and costs for various alternative treatment methods is also needed. As with the hazardous and solid waste streams, a combination of management options may prove optimal for managing medical waste once the material composition of its components is considered.

That is, landfilling, incineration, and other treatment alternatives, as well as recycling and waste reduction all may be viable management options for medical waste—when it is considered on a waste component basis. Ultimately, this may help to control costs and minimize any hazards associated with medical waste management. This is one way, given the experience gained in regulating other waste streams, that programs to manage medical wastes can be devised wisely and efficiently in order to alleviate public concern, protect workers, and provide environmental protection.

WASTE CHARACTERISTICS AND TYPES—TREATMENT IMPLICATIONS

Examining various treatment options underscores the importance of considering the properties of different types of medical waste and matching them to the capabilities of the treatment technologies. Although the medical waste stream is heterogeneous, the focus of concern is on the portion of the waste stream termed "infectious," and how these wastes are classified (e.g., solid, hazardous, or special) and regulated. The regulated waste stream, i.e., the medical wastes covered by MWTA, includes infectious, potentially infectious, and some wastes identified as requiring special handling. Most estimates are that 10 to 15 percent of medical wastes generated by hospitals are infectious, although this figure can range as high as 80 percent depending on the generator's definition. Determining which portion of medical waste is infectious remains at the heart of definitional issues. How infectious waste is defined can greatly affect the cost of waste management, and ultimately the choice of disposal options (114).[5]

Currently, both aesthetic considerations and health risks posed by medical wastes can lead to the classification of a medical waste as infectious and/or regulated and requiring special management. The State of Washington has defined infectious waste based on risk criteria, particularly the determination of "infectious disease causation potential" (139). **A consensus on which medical waste warrants special regulation and management might be forged if the definition of regulated medical waste is based on the potential health risks associated with the waste (i.e., the ability of a particular medical waste—given organism concentration, ability of the waste to penetrate skin, etc.—to pose a risk beyond that associated with MSW to transmit infectious disease).**

As noted, no consensus exists on the types of medical wastes that should be designated as infectious or that require special handling, although several categories of wastes are included in most lists (114; also see table 2). Under MWTA (see below), EPA has listed seven types of medical waste (commonly and hereafter referred to as "regulated waste types") to be tracked in the demonstration program. These are:

1. microbiological wastes (cultures and stocks of infectious wastes and associated biologicals that can cause disease in humans);
2. human blood and blood products (including serum, plasma, and other blood components);

[5]Some confusion was created over the Centers for Disease Control (CDC) universal precautions guidance issued in August 1987, that suggested that *all* patients be considered potentially infected with human immunodeficiency virus (HIV) (i.e., the virus which causes acquired immunodeficiency syndrome, AIDS) and/or other blood-borne pathogens and that workers should adhere to rigorous infection-control procedures. In October 1987, CDC issued a joint advisory notice with the Department of Labor further addressing protection against occupational exposure to Hepatitis B (HBV) and HIV. After these advisories led to a great inflation of the amount of waste designated as infectious, the CDC issued a clarification in August 1988, indicating to which types of secretions and circumstances its recommendations applied and that CDC did not intend for generators to alter waste management procedures, but only meant to protect health-care workers. In May 1989, the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor issued a proposed job health standard for protecting health-care workers from blood-borne diseases.

Table 2—Types of Wastes Designated as Infectious by Various Entities

Waste category	EPA/ MWTA	EPA[a]	CDC	MA	CA	IL	NY	SC	WI	Percentage of hospitals[b]
Microbiological[c]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	99.0
Human blood and blood products	Yes	Yes	Yes	Yes	No[d]	Yes	Yes	Yes	Yes	93.7
Isolation wastes	Yes	Yes	Optional[e]	Yes	Yes	Yes	Yes[f]	Yes	No	94.4
Pathological wastes[g]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	95.6
Contaminated sharps[h]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	98.6
Contaminated animal carcasses, body and bedding	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	90.1
Uncontaminated sharps	Yes	No	No	Yes	No	No	Yes	No	No	N/A
Other contaminated wastes:										
Miscellaneous laboratory wastes		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	88.8
Surgery and autopsy wastes		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	83.2 & 91.9, respectively
Dialysis unit wastes		Optional[i]	No	Yes	Yes	No	Yes[f]	No	Yes	83.4
Equipment		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	N/A
Any other infectious waste		No	No	Yes	Yes	Yes	Yes	Yes	Yes	Varying percentages

[a]Based on recommendations in EPA Guidance Document (U.S. Environmental Protection Agency, *Guide for Infectious Waste Management*, EPA/530-SW-86-014 (Washington, DC: May 1986); see discussion in U.S. Congress, Office of Technology Assessment, *Issues in Medical Waste Management—Background Paper*, OTA-BP-O-49 (Washington, DC: U.S. Government Printing Office, October 1988).

[b]Percentage of hospitals designating this waste category, according to a survey completed for the American Hospital Association. W. Rutala, W.W. Odette, and G. Samsa, "Management of Infectious Waste by U.S. Hospitals," *Journal of American Medical Association* 262:1635-1640, 1989.

[c]Such as cultures and stocks of infectious agents.

[d]Human blood and blood products that are proven to contain pathogens arae subject to California's infectious waste law and regulations.

[e]CDC recommends that this waste be treated according to hospital policy.

[f]The New York State Commissioner of Environmental Conservation may exclude this category.

[g]Such as human body parts, tissues, fluids, and organs.

[h]Such as syringes, needles, scalpel blades, and glass.

[i]EPA's 1986 guidance states that the decision to handle these wastes as infectious should be made by a responsible, authorized person or committee at the individual facility.

SOURCE: Office of Technology Assessment, 1990; based on U.S. General Accounting Office, *Medical Waste Regulation: Health and Environmental Risks Need To Be Fully Assessed*, GAO/RCED-90-86 (Washington, DC: March 1990).

3. pathological wastes of human origin (including tissues, organs, and body parts removed during surgery or autopsy);
4. contaminated animal wastes (i.e., animal carcasses, body parts, and bedding exposed to infectious agents during medical research, pharmaceutical testing, or production of biologicals);
5. isolation wastes (wastes associated with animals or humans known to be infected with *highly* communicable diseases);
6. contaminated sharps (includes hypodermic needles, scalpels, broken glass); and
7. uncontaminated sharps.[6]

Other waste categories that EPA had to consider for inclusion in MWTA demonstration program are: wastes from surgery or autopsy that were in contact with infectious agents (e.g., sponges, soiled dressings, drapes, surgical gloves, drainage sets); dialysis wastes that were in contact with blood; discarded medical equipment and parts that were in contact with infectious agents; and laboratory wastes that were in contact with infectious agents (e.g., laboratory coats, slides and cover slips). EPA determined that potentially infectious items from these waste categories are covered by the other seven regulated waste types. It is interesting to note that according to a recent survey sponsored by the American Hospital Association, the vast majority of the 441 randomly selected hospitals designated six of the seven categories above as infectious (the exception being unused sharps) (95).

Wastes within each of these regulated waste type categories can have different chemical (hazardous, radioactive, or nonhazardous) and physical (liquid, gas, or solid) characteristics that are important to consider in selection of the most appropriate treatment method. Clearly, different types of medical practices by physicians, types of hospitals, and different departments within a hospital generate different types and quantities of the regulated waste types (123, 29) (see table 3). Therefore, it is reasonable to assume that just as hospital type and size and occupancy rate are important determinants of generation rates of medical wastes, they are also key factors affecting the chemical and physical make-up of the wastes. That is, general medical and surgical hospitals will generate a different quantity and mix of wastes than psychiatric or other specialty hospitals (e.g., chronic disease, orthopedic, and eye/ear/nose/throat hospitals).

Chemical Characteristics

Hazardous Constituents

Waste from a medical facility may contain cytotoxic chemicals, laboratory solvents, toxic metals, low-level radioactive waste, or waste contaminated with human pathogenic microorganisms. Cytotoxic chemicals are hazardous pharmaceuticals used in chemotherapy, and seven such compounds are on the RCRA "U" list of hazardous waste.[7] This means that they cannot be disposed of in bulk quantities in medical waste incinerators without a RCRA hazardous waste incinerator permit. It is also true that these RCRA hazardous wastes could not be treated by most nonincineration treatment methods. Yet, given that these substances are usually encountered as "trace" contaminants, rather than "bulk wastes," they are not managed as RCRA hazardous wastes, and can legally be disposed of with other medical wastes.

Laboratory solvents and other types of hazardous chemicals are commonly found in medical wastes, and many of these are also listed as hazardous wastes under RCRA.[8] Although these wastes should be managed separately from other medical wastes as RCRA hazardous wastes, like cytotoxic compounds, sometimes they are so intimately mixed with medi-

[6]See GAO (134) for a more complete discussion of the EPA's determinations for inclusion and specification of the different waste types.

[7]These are: chlorambucil, cyclophosphamide, duanamycin, melphalan, mitomycin, stretozotocin, and uracil mustard. These cytotoxic compounds are a small fraction of all cytotoxic agents. The total amount of cytotoxic compounds incinerated is not known and little is known of the potential threat from cytotoxic emissions.

Indeed, data for cytotoxic emissions is lacking and conditions necessary to destroy cytotoxic compounds are not known. A conservative assumption is that 1,800 °F (1,260 K) would ensure complete destruction of cytotoxic compounds, although destruction is also dependent on residence time and mixing (12, 41). As part of its testing program (at two incinerators) for developing standards for new medical waste incinerators, EPA is conducting tests to determine the destruction efficiency of the two test medical waste incinerators of hexochlorobenzene as a surrogate for cytotoxic chemicals (the tests will be conducted at a secondary chamber temperature of 2,000 °F) (41).

[8]Hazardous solvents typically found in medical waste include: acetone, 2-butanol, butyl alcohol, cyclohexane, diethyl ether, ethyl acetate, ethyl alcohol, formaldehyde, heptane, hexane, methyl alcohol, methyl cellosolve, pentane, petroleum ether, 2-propanol, sec-butyl alcohol, tert-butyl alcohol, tetrahydrofuran, and xylene (12). Many of the chemicals used as laboratory solvents and all but the seven chemotherapeutics listed as hazardous waste can be disposed of legally through the sewer system (141).

Table 3—Percentages of Waste Types Produced at Different Medical/Health-Care Facilities in the State of Washington

	Type of facility										
All cases	Total	Funeral	Nursing	Vet	Lab	Surgery centers	Hospital	Clinic	Dental	Research	Medical
Wastes produced (*)	100% (350)	100% (32)	100% (43)	100% (49)	100% (25)	100% (8)	100% (51)	100% (60)	100% (32)	100% (17)	100% (33)
Wastes with excretions/secretions	75	84	91	84	64	63	96	67	59	29	70
Microbiological	42	0	16	41	44	25	92	57	3	65	42
Human blood and blood products	56	88	23	2	88	38	96	63	44	53	64
Animal blood and blood products	15	0	0	69	12	0	10	0	0	59	3
Pathological	44	28	5	86	32	50	88	32	31	24	30
Sharps	94	94	98	96	92	100	98	87	91	88	100
Wastes from surgery	64	69	16	92	8	88	98	67	78	12	76
Dialysis unit wastes	7	19	0	0	0	0	25	5	0	6	3
Contaminated animal carcasses/ bedding	14	3	0	76	0	0	4	0	0	47	0
Isolation patients' wastes	32	47	77	37	8	0	78	5	0	0	6
Radioactive wastes	15	0	0	0	40	0	49	10	0	53	9
Chemotherapy wastes	18	9	2	10	12	13	69	15	0	0	18
None of the above	3	3	0	0	8	0	2	10	3	6	0

(*) percentages may not add to 100 percent because of multiple responses.

SOURCE: Washington State Department of Ecology, Solid and Hazardous Waste Program, "Report to the Legislature: Washington State Infectious Waste Project and Attachments" (Olympia, WA: Dec. 30, 1989).

cal wastes that separation is impractical.[9] When hazardous materials are mixed with infectious wastes in this way, the hazardous portion needs to be the component that is given primary consideration for proper treatment. Some generators prefer a treatment method (e.g., incineration) that is practical for both hazardous and infectious materials so that only one treatment form is required. Alternatively, the infectious nature can sometimes by addressed through thorough disinfection before being sent for hazardous treatment to avoid exposure to infectious agents during the handling process (43).

These substances may be precursors in the formation of dioxins (dibenzo-p-dioxin, PCDD) and furans (dibenzofuran, PCDF), suspected carcinogens, when chlorine is present during incineration (12). Metals that can be toxic, such as lead, cadmium, chromium and mercury, are present in medical waste. One study completed by the University of California at Davis concluded that plastics in the waste contributed most of the lead and cadmium (12). Although lead was found in many materials, plastics were the primary source. Both cadmium and lead are components in common pigments and are used as thermo- and photo-stabilizers in plastics, such as may be used to color red bags used for infectious waste (12).

Low-Level Radioactive Wastes

Low-level radioactive wastes (LLW) are produced in health-care settings from administering radiopharmaceuticals and performing nuclear medicine procedures and radio-immunology procedures. In fact, medical and research facilities produce less than 5 percent of the total volume of LLW generated in the United States (117). It should be noted that unlike radioactive materials used in powerplants or the production of weapons, medically useful radioactive tracers, which are extremely valuable in diagnostic procedures and medical research (e.g., testing new drugs), usually have a very short half-life (117). That is, typically, half of the material decays to a nonradioactive form in hours to days. Hospitals usually do not store LLW with isotopes with half-lives greater than 8 days given the significant amount of storage space this would involve (117, 73). Currently, there are only three disposal sites for storage of LLW in the United States.[10] The temporary closure of two of these sites in 1979 set in motion Federal efforts to encourage States to establish more sites and spurred medical and health-care facilities to devise a variety of new reduction and management strategies for LLW (see box A).[11]

Biological Characteristics

Pathogens in Wastes

Pathogens in medical wastes include a wide range of bacteria, viruses, and other microorganisms (e.g., mycobacteria, yeasts, fungi, parasites, and rickettsia) that are sufficiently virulent to infect a human body if they are given an exposure route (e.g., a puncture or an open wound) (12, 3).[12] Clearly, pathogens are also present in MSW (e.g., contributed by disposable diapers, sanitary napkins, tissues, etc.), although the likely higher concentrations of pathogens in medical waste and the level of pathogenicity of organisms found in health-care institutions and their increased resistance to antibiotics may make them a greater threat for those who handle the material and may also introduce the possibility of public health concerns (43).

The important issue is the viability of the pathogens during treatment and disposal and their potential to transmit disease. Some degree of pathogen survival in an MSW landfill is expected, for example, but the likelihood of pathogens migrating from a properly operated landfill is considered extremely low, based on available research (110, 138, 116). Even so, there have been few scientifically designed experiments to measure for pathogens, e.g., in leachate or waters downstream from a landfill (41).[13]

[9]That is, radioactive tracers which are commonly used for diagnostic purposes are commonly mixed with solvents during the extractive procedures and should be handled as hazardous waste, according to EPA (141).

[10]These are in Washington State, Nevada, and South Carolina. Not surprisingly, these States object to being the Nation's only disposal sites.

[11]Congress passed the Low-Level Radioactive Waste Policy Act in 1980 (later amended in 1985), which makes each State responsible for providing disposal capacity for its own LLW and encourages States to form compacts (which can exclude wastes from nonmembership States) to provide disposal capacity. Too little waste is generated to justify a need for a LLW disposal site in every State (see 117).

[12]Medical wastes and MSW can contain such organisms as: staphylococcus aureus, candida albicans, pseudomonas, clostidium perfringens, staphylococcus epidermidis, and respiratory streptococci (12).

[13]For example, microorganisms such as Salmonella and Hepatitus virus can be carried in water, and can survive well (43).

Box A—Management of Medical Low-Level Radioactive Waste (LLW)

Medical LLW is treated in several ways, depending on the physical form of the waste (e.g., liquid or solid) and the type and quantity of its radioactivity. The medical LLW with short-lived radionuclides (i.e., less than 8 days) in low concentrations is typically stored until its radioactivity is below detectable levels. The waste can then be disposed of as nonradioactive waste. Certain liquid medical LLW that meets limits established by the U.S. Nuclear Regulatory Commission (NRC) for radioactivity concentration and solubility in water can be disposed of through the sewer. Certain solid medical LLW (e.g., liquid scintillation counting media and biologicals) can be disposed of without regard to its radioactivity, where the radiological hazard is considered small, but the nonradiological hazards warrant special handling and disposal.[1] The NRC considers controlled incineration of low-activity medical LLW to be adequate treatment because any radioactivity released during the burning is well below accepted environmental levels. Medical LLW, which cannot be stored for decay, disposed to the sewer, or incinerated, is typically land disposed.[2]

The NRC distinguishes four classes of LLW: Class A Waste (contains low levels of radiation and requires no shielding to protect workers; decays in less than 100 years and represents about 97 percent of LLW); and Class B, Class C, and Greater Than Class C (all three of which require shielding and can remain harmful for 300 or more years). In addition, LLW that is mixed with hazardous waste is referred to as "mixed waste" (e.g., organic liquids, such as scintillation fluids used in diagnostic tests, comprise the largest volume of mixed LLW). Mixed LLW is regulated by both the NRC and the EPA; at this time there are no licensed facilities to accept mixed LLW (117).[3]

Since 1980, total LLW volumes have been reduced by 55 percent, and estimates for reducing medical LLW could be 70 percent or higher (117, 140, 136). This reduction is due to efforts by generators to reduce volume, costs, and risks associated with LLW management. The waste minimization techniques include improved management (i.e., segregation of nonradioactive from radioactive waste), substitution of nonradioactive materials, and operational practices to prevent materials from becoming contaminated (117, 24).[4] Although volume reduction to date has already reduced the amount of LLW requiring disposal, the NRC and Agreement States have considered reclassifying some LLW to a category for which no special handling or management would be required. Previously, public concern over potential health risks associated with any such reclassification has worked against adoption of any national proposal to reclassify LLW in this way. Recently, however, the NRC announced a controversial new policy that deregulates certain low-level radioactive wastes considered nonhazardous. This so-called "below regulatory concern" (BRC) waste would include such items as trace amounts of radioactive material and mildly contaminated bodies of laboratory animals, which health-care and medical research laboratories could dispose of with municipal solid waste (135).

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[1]That is, such waste would be managed as a hazardous waste if other components of the waste are hazardous or as medical waste if the waste is non-hazardous (117, 70, 24).

[2]Estimates are that two 10-foot-deep trenches, each about the size of a football field, are required to meet the amount of LLW from medical and health-care settings annually in the United States. However, the exact amount of medical LLW is not known (1). (See ref. 117 for a detailed discussion of these site requirements, the efforts to date to form compacts, and other issues regarding LLW management.)

[3]An exception of this statement is scintillation fluids. For the most part, these substances can be treated (e.g., incinerated) because the concentration of radionuclides in them falls below limits set in the NRC's Biomedical Rule (10 CFR, Part 20.306). Other higher concentrated medical mixed wastes, however, are left with no treatment or disposal options.

[4]Interestingly, medical LLW is one area of waste management for which the medical profession has been encouraging governmental action to ensure the availability of disposal sites, and thereby the continued use of radioactive isotopes. For example, the American College of Nuclear Physicians has "strongly encouraged officials of all levels of government to achieve a timely resolution of the [LLW issues], stressing public safety, economy, and preservation of all the benefits society enjoys that depend on radioactive isotopes" (19).

A risk evaluation completed in King County, Washington (Seattle area), concluded that reduction in the risks posed by medical waste will best be achieved by eliminating modes of transmission between humans and the pathogens in the wastes (111). Pathogens are easily destroyed when exposed to the mean gas temperature and residence times encountered in incineration. The main potential routes of exposure of concern, then, are through escapes of gases containing pathogens during loading, and pathogen survival in the ash or air emissions due to poor operating conditions (see discussion in 134). To date few test results have been published documenting pathogen survival after incineration, and further study has been recommended (134). EPA is planning to address the issue of potential pathogen survival in the incineration cycle in its current study of medical waste incineration (33). The results of

Table 4—Characteristics of Medical Waste

Waste component	Bulk density as fired (lb/cu.ft.)	Moisture content as fired (weight percent)	Heating value as fired (Btu/lb)
Human anatomical	50-75	70-90	800-3,600
Plastics	5-144	0-1	13,860-20,000
Swabs, absorbents	5-62	0-30	5,600-12,000
Alcohol, disinfectants	48-62	0-0.2	10,980-14,000
Infected animals	30-80	60-90	900-6,400
Glass	175-225	0	0
Bedding, shavings, paper, fecal matter	20-46	10-50	4,000-8,100
Gauze, pads, swabs, garments, paper, cellulose	5-62	0-30	5,600-12,000
Sharps, needles	450-500	0-1	0-60
Fluids, residuals	62-63	80-100	0-2,000

KEY: 1 lb/cu.ft. = 16.03 kg/m^3
1 Btu/lb = 2.324 J/g

SOURCE: T. Milburn, "Biomedical Waste Incineration BACT Application Considerations," Proceedings of the Third National Symposium on Infectious Waste Management, Chicago, IL, April 1989, as cited in R. Barton, G. Hassel, W. Lanier, and W. Seeker, *State of the Art Assessment of Medical Waste Thermal Treatment*, EPA Contract 68-03-3365 and ARB Contract A832-155 (Irvine, CA: Energy & Environmental Research Corp., 1989).

this effort will be reported in the Agency's final report to Congress, although EPA anticipates that further studies on the issue beyond this effort may be warranted (141).

Disinfection rates for nonincineration treatment alternatives can also be high, if the treatment system is properly designed and operated. A source of general concern and confusion is the extent to which various treatment alternatives "disinfect" medical wastes. The efficacy of a treatment method should be demonstrated by development of an appropriate biological testing program. It appears reasonable that the degree of disinfection not be required to exceed microbial and virulence levels that may generally be found in MSW (111).

Physical Characteristics

The basic physical forms of medical wastes (solid, liquid, and gas) should be taken into account for their handling and management. Segregation of wastes by health-care facilities into types based on these physical states is likely to occur, e.g., liquid wastes, non-sharp/solid wastes, sharp wastes (see tables 4 and 5).

Both physical characteristics (e.g., heat value and moisture content) of waste components and the biological make-up and chemical (elemental) composition of the waste are important determinants of the most appropriate treatment technology and have important impacts for that treatment. Despite the fact that medical waste is heterogeneous in its physical and chemical nature, the waste is rarely managed initially as a mixture of all the wastes from the facility. That is, it is likely that a medical facility will

Table 5—Comparison of the Composition of Medical and Municipal Waste

Waste component	Amount in waste, percent by weight: Medical waste	Municipal waste	Hazardous waste[a]
Dry cellulosic solids	45.1	54.2	0
Wet cellulosic solids	18.0	12.2	0
Plastics	14.2	7.4	12
Rubber	0.7		
Solvents			58
Noncombustibles	20.4	26.2	
Pathological	1.6		
Heating value (Btu/lb)	6,000	4,335	6,030

[a]For a typical commercial incinerator accepting a broad range of wastes.
1 Btu/lb = 2.324 J/g

SOURCE: D. Campbell, "Hospital Waste Management in Canada," Proceedings of the National Workshops on Hospital Waste Incineration and Hospital Sterilization, U.S. Environmental Protection Agency, San Francisco, CA, May 1988, as cited in R. Barton, G. Hassel, W. Lanier, and W. Seeker, *State of the Art Assessment of Medical Waste Thermal Treatment*, EPA Contract 68-03-3365 and ARB Contract A832-155 (Irvine, CA: Energy & Environmental Research Corp., 1989).

collect wastes from various departments *separately* (i.e., computer printouts are collected from the accounting department; kitchen waste, patient waste, etc. are collected separately), although they may be mixed for treatment (e.g., incineration) (12, 139).

Given the important impact chemical characteristics of wastes can have on the effectiveness of various treatment technologies to safely manage medical waste, it appears sensible to keep wastes separate based on their physical and chemical properties, at least as carefully as possible into hazardous, solid, and regulated medical/infectious waste categories, to ensure the wastes receive appropriate treatment/management. This will be true whether incineration or nonincineration treatment

technologies are used. It will also facilitate efforts to recycle wastes when feasible and identify opportunities for waste reduction.

EPA adopted as part of its regulations under MWTA (40 CFR Part 259) segregation requirements to control and reduce costs for waste disposal and minimize worker exposure to certain medical wastes. The Agency reports, however, that facilities in MWTA demonstration program base their segregation policies primarily on the basis of convenience and barriers associated with reeducating their staff to change management practices (141). A recent study commissioned by the New York City Health & Hospitals Corp. and conducted by Waste Tech, finds that facilities required to comply with MWTA could reduce the cost and volume of their waste management through more careful segregation and reduction practices (62, 63). Waste management companies also report that segregation at the point of generation is key to containing handling and treatment costs, as well as assisting in appropriate recycling opportunities (43) (see ch. 4).